1 **(a)** Human populations have herded cattle for milk for around 9 000 years. Artificial selection over this time has resulted in the modern dairy cow.

(i) State **three** phenotypic traits (characteristics) that have been selected for in dairy cows.

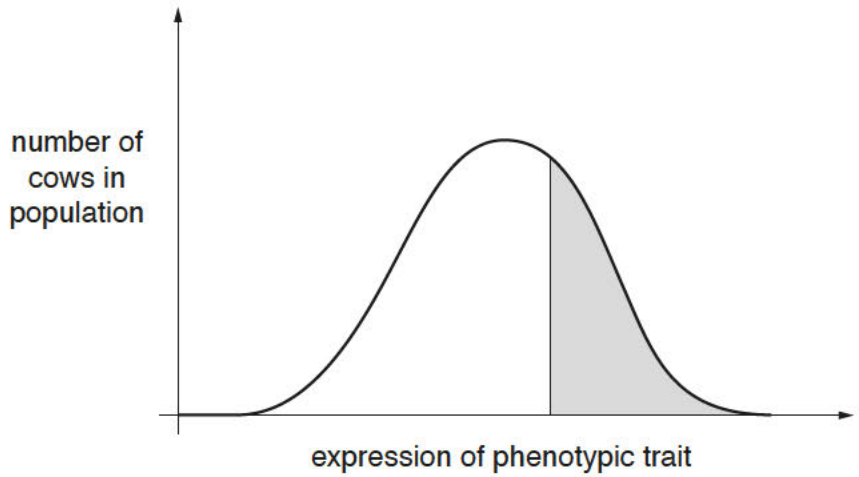
1 .....

2 .....

3 ..... **[3]**

(ii) Fig. 1.1 shows the pattern of variation of a phenotypic trait in a herd of dairy cows. The shaded part of the graph indicates those cows that are chosen to breed.

Draw, **on Fig. 1.1**, a second curve to show the pattern of variation in the next generation.



[2]

Fig. 1.1

(iii) In recent years, artificial selection of dairy cows has been helped by modern reproductive technology.

Name **two** modern techniques or procedures that can be used in the selective breeding of dairy cows.

1 .....

2 ..... **[2]**

(b) Lactase is an enzyme that is necessary to digest lactose sugar in milk.

In some parts of the world, animals are not farmed for milk and no dairy products are eaten. Adult humans that are native to these parts of the world do not produce lactase.

In areas where animals are farmed for milk, native adult humans do produce lactase. In these populations, a new allele has arisen by gene mutation.

(i) State what is meant by gene mutation.

.....

..... **[1]**

(ii) Over time, the frequency of this new allele increased in the gene pool of the human populations whose diet included milk.

Name the process by which this increase occurred.

..... **[1]**

(c) **(i)** All human babies produce the enzyme lactase. The genetic change that allows adults to produce this enzyme is thought to involve a mutation in a regulatory gene. This mutation causes the structural gene to be expressed in adults.

Distinguish between the terms 'regulatory gene' and 'structural gene'.

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..... **[2]**

(ii) Adult humans who cannot produce the enzyme lactase are described as lactose-intolerant and cannot drink milk without experiencing health problems. However, lactose-intolerant people can safely eat yogurt.

Yogurt is produced from milk that is fermented by bacteria. These bacteria perform anaerobic respiration, using carbohydrate as their respiratory substrate.

Suggest why yogurt is a suitable food for lactose-intolerant people.

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..... **[2]**

(d) The control of the expression of the *lac* operon genes, which allow uptake and digestion of lactose in the bacterium *Escherichia coli*, is well known.

Fig. 1.2 shows the arrangement of the elements of the *lac* operon.

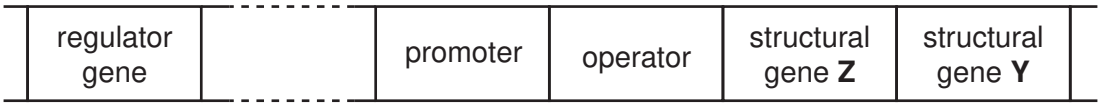


Fig. 1.2

Describe how genes **Z** and **Y** are switched on in bacteria that are moved to a nutrient medium that contains lactose.

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..... **[3]**

[Total: 16]

2 Four different eye pigments in the fruit fly, *Drosophila melanogaster,* are made from the amino acid tryptophan. A simplified metabolic pathway of pigment production is shown in Fig. 2.1.

Three different gene loci control the pathway. Each locus has two alleles. These alleles are **V** or **v**, **C** or **c** and **B** or **b**, as shown in Fig. 2.1.

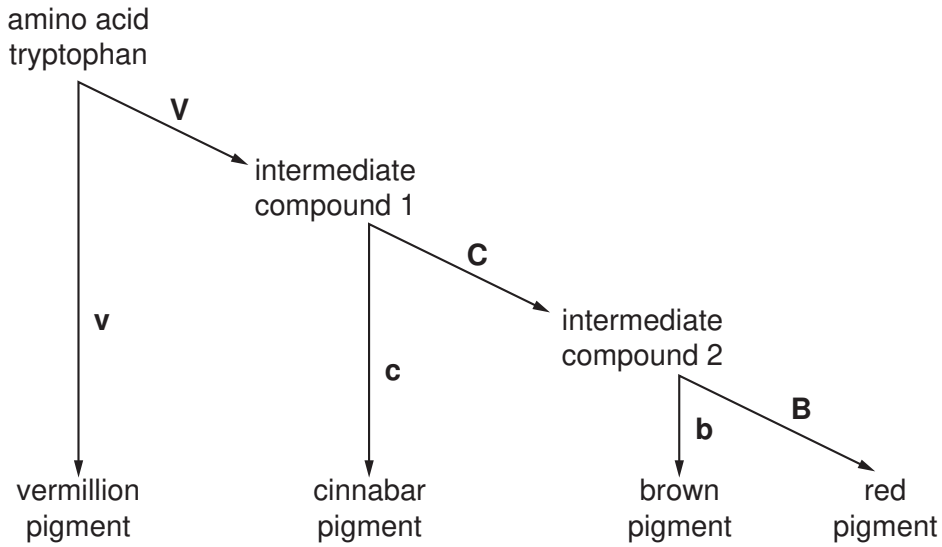


Fig. 2.1

(a) (i) Using the information in Fig. 2.1, deduce the phenotypes of flies with the following genotypes:

genotype	*phenotype*
VvCcBb	.....
vvCCBB	.....
VvccBB	..... **[3]**

(ii) State the term that is applied to this type of gene interaction.

..... **[1]**

(iii) Explain how the products **coded for** by the genes interact to give the different pigments.

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..... **[3]**

(b) A mutation in another gene at another locus in *Drosophila* gives rise to white-eyed flies. The red eye allele of this gene (**R**) is known to be dominant to the white eye allele (**r**).

A student crossed a red-eyed fly with a white-eyed fly, expecting to get an F1 generation of red-eyed flies. In fact, the results were as shown in Table 2.1.

Table 2.1

phenotype of fly	number of offspring
red-eyed female	27
red-eyed male	0
white-eyed female	0
white-eyed male	23

(i) The student first suggested that the reason for there being red-eyed and white-eyed flies in the offspring was that the red-eyed parent was heterozygous.

Explain why this **cannot** be the correct explanation for the results shown in Table 2.1.

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..... **[2]**

(ii) In *Drosophila*, the males are the heterogametic sex, possessing two different sex chromosomes, X and Y.

Draw a genetic diagram to show how the results shown in Table 2.1 could have been produced.

Parental genotypes …… ……

Gametes …… ……

F_1 genotypes …… ……

[3]

(iii) The chi-squared (χ^2) test can be used to analyse the results in Table 2.1.

The expected ratio of red-eyed females to white-eyed males is 1:1.

Use Table 2.2 to calculate a value for chi-squared (χ^2).

$$\chi^2 = \Sigma \frac{(O - E)^2}{E} \qquad df = n - 1$$

Key to symbols:

Σ = 'sum of …'
df = degrees of freedom
n = number of classes
O = observed value
E = expected value

Table 2.2

phenotype of fly	O	E	O – E	$(O - E)^2$	$\frac{(O - E)^2}{E}$
red-eyed female					
white-eyed male					

χ^2 = ...

Use your calculated value of χ^2 and the table of probabilities shown in Table 2.3 to test the significance of the difference between the observed and expected results.

State your conclusion in the space below.

Table 2.3

degrees of freedom	probability, p			
	0.90	0.50	0.10	0.05
1	0.02	0.45	2.71	3.84
2	0.21	1.39	4.61	5.99

Conclusion .....

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..... **[4]**

[Total: 16]

3 The Galapagos Islands are 600 miles away from the nearest land mass, South America. They consist of 15 main islands, 3 smaller islands, and 107 rocks and islets. This collection of islands is home to many endemic species of animals and plants. This means that these species are found nowhere else in the world.

(a) Explain, using scientific terms, why a collection of small islands remote from the mainland provides optimal conditions for speciation.

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..... **[2]**

(b) In 1978, the United Nations (UN) declared the Galapagos Islands a World Heritage Site. This led to a rise in the resident human population and the number of visitors to the Islands.

Table 2.1 shows how the number of people living on and visiting the Galapagos Islands changed between 1980 and 2005.

Year	Resident population	Number of visitors
1980	5500	16000
1985	7000	19000
1990	9500	42000
1995	12500	58000
2000	17500	68000
2005	27500	125000

Table 2.1

(i) Calculate the percentage increase in the number of visitors to the Galapagos Islands between 1980 and 2005.

Show your working. **Give your answer to the nearest whole number.**

Answer = ...% **[2]**

(ii) Outline the main ways in which increased human presence and activity have put endemic species on the Galapagos Islands, and in the sea around them, at risk of extinction.

In your answer you should link the ecological pressures imposed by human activity to examples of Galapagos Island species that have been affected.

[7]

(c) In 2007, the United Nations (UN) put the Galapagos Islands on its Red List of endangered sites. The Galapagos government's response to this action included making new laws and placing restrictions on human activity, issuing eviction orders and culling introduced species of animals.

Suggest **one** economic and **one** ethical problem that might have arisen from this 2007 UN decision.

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..... **[2]**

[Total: 13]

4 **(a)** The traditional English folk song, *The Derby Ram*, contains the lyric:

"As I went out to Derby, all on a market day
I spied the biggest ram, sir, that ever was fed on hay"

The song is likely to have been inspired by the successes of farmers in the eighteenth century who developed a sheep known as the 'Dishly Ram'. This ram gave rise to a breed which grew more quickly, producing more wool and meat than other varieties of sheep.

(i) Explain how it would be possible for farmers in the eighteenth century to produce a larger, more profitable variety of sheep from an existing flock of sheep.

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..... **[3]**

(ii) Since the eighteenth century, other ways of improving productivity in sheep have been developed.

State **one** further way of improving productivity that is used by modern farmers.

..... **[1]**

(b) Crop yield can be improved by the use of fertilisers. In the eighteenth century, these are likely to have been organic fertilisers in the form of manure or compost.

(i) Suggest how organic fertilisers improve the yield of plant crops.

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..... **[3]**

(ii) Inorganic fertilisers are not directly toxic to living organisms. However, the excessive use of these fertilisers can lead to a reduction in the biodiversity of farmland.

Suggest how the excessive use of inorganic fertilisers on **farmland** can cause a reduction in its biodiversity.

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..... **[2]**

(iii) Explain why a reduction in biodiversity may present problems for **agriculture** in the future.

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..... **[3]**

[Total: 12]

5 **(a)** The fruit fly, *Drosophila melanogaster*, the zebra fish, *Danio rerio*, and the mouse, *Mus musculus*, have all been used by scientists to find out more about how genes control development in all animals, including humans. They are described as 'model organisms'.

(i) Suggest why information gained from studying such model organisms can be applied to humans.

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..... **[2]**

(ii) Suggest **two** characteristics that researchers should look for when choosing an organism for research into how genes control development.

1 .....

2 ..... **[2]**

(b) Fig. 3.1 and Fig. 3.2, **on the insert**, show the heads of two *Drosophila* fruit flies.

Fig. 3.1 shows a normal wild type fly.
Fig. 3.2 shows a mutant fly.

(i) Name the type of microscope used to take the two pictures.

..... **[2]**

(ii) State one significant difference between the two heads.

.....

..... **[1]**

(iii) Name the type of gene which, if mutated, gives rise to dramatic changes in body plan.

..... **[1]**

(c) Describe how the information coded on genes is used to synthesise polypeptides **and** how these polypeptides control the physical development of an organism.

In your answer, you should consider both the synthesis of polypeptides and their roles.

[8]

[Total: 16]